Iris Recognition Reliability: Authenticity Assessment + Influence of Illuminant Wavelength

Adam Czajka

Biometric Laboratories
NASK & Warsaw University of Technology
adam.czajka@nask.pl

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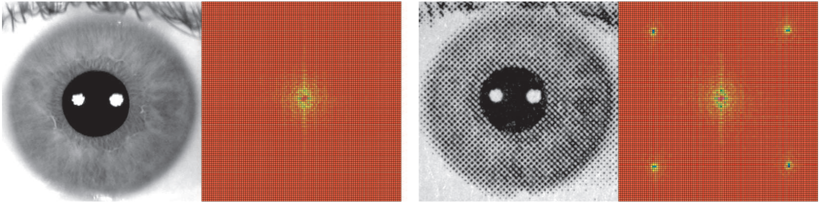
Agenda

1. Authenticity assessment
   - Frequency analysis
   - Method variants
   - Selected results and conclusions
2. Influence of Illumination Wavelength
   - Equipment and database
   - Selected results and conclusions

Frequency analysis for authenticity assessment

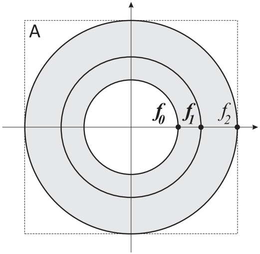


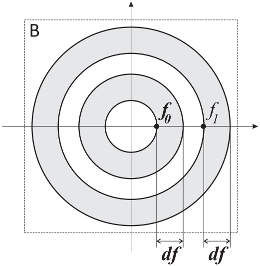
Images and corresponding amplitude spectra
for authentic iris (left) vs. iris printout (right)

1. Straightforward method for detection of regular occurrence of dots within the image
2. Image used for recognition may be employed (i.e. no additional hardware or new capture procedures are required)
3. (Rough) iris segmentation is required: 'easy' for authentic irises, unpredictable for artefacts

Method variants

Frequency windows





A: Two fixed windows

$$q_A = \frac{h(f_1, f_2)}{h(f_0, f_1)}$$

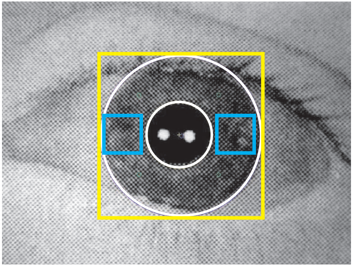
B: One fixed and one moving window

$$q_B = \max_{f_1} \frac{h(f_1, f_1 + df)}{h(f_0, f_0 + df)}$$

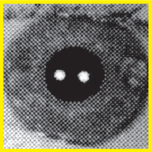
where f_0, f_1 are parameters in A, f_0, df are parameters in B, h calculates maximum (or average) values within frequency window (raw and log amplitudes are considered)

'Alien frequencies' expected in the inner or the outer window

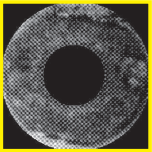
Method variants
ROI selection



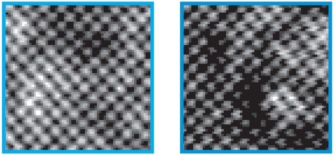
Iris printout image



Cropped (C)



Cropped
and masked (CM)



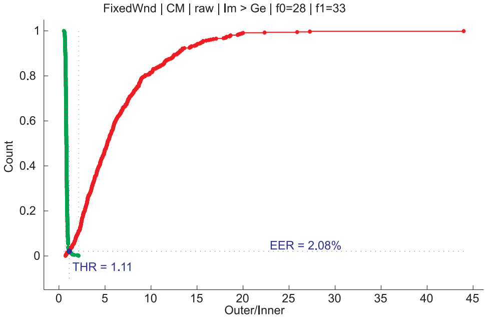
Segments (S)

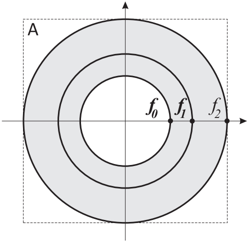
Databases

1. Equipment
   - DB1: IrisCUBE (prototype) camera, HP LaserJet 1100
   - DB2, DB3, DB4: IrisGuard AD100, Lexmark 534
   - DB5: IrisGuard AD100, Lexmark 534 & HP LaserJet 1320
2. Approximately 700 images of iris printouts (and images of the corresponding authentic eyes)
   - all printouts used to successfully spoof an example commercial camera

Selected results: best accuracy (EER)

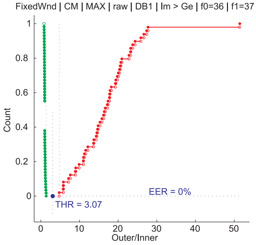
Winner: fixed window (A), raw amplitude, cropped and masked (all databases mixed)

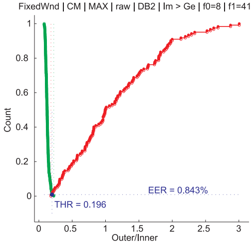


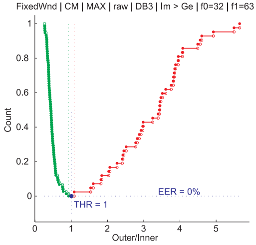


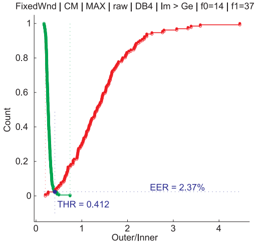
Selected results: best accuracy (EER)

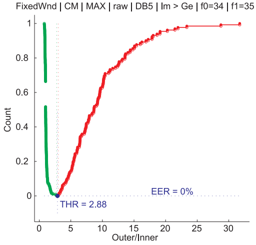
Winner: fixed window (A), raw amplitude, cropped and masked

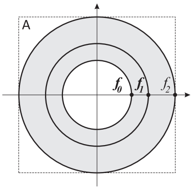






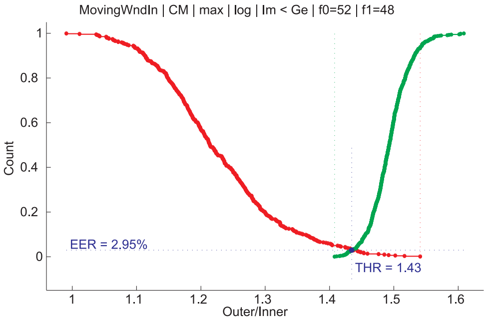


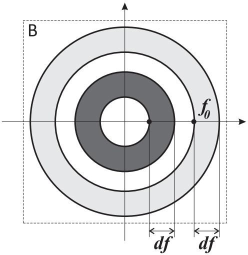




Selected results:
best FAR (FNDR) for FRR (FADR) = 0

Winner: moving window (B), log amplitude, cropped and masked (all databases mixed)





Selected results: best FAR (FNDR) for FRR (FADR) = 0

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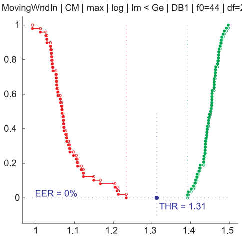
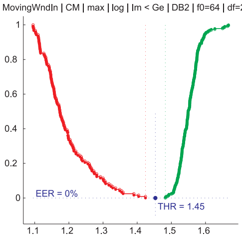
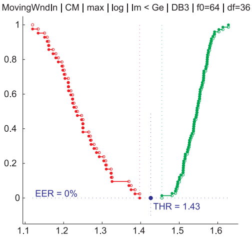
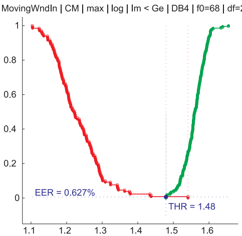
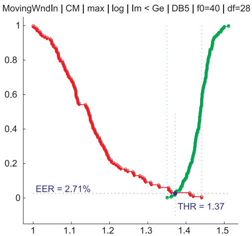
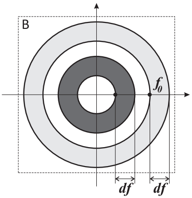












Conclusions

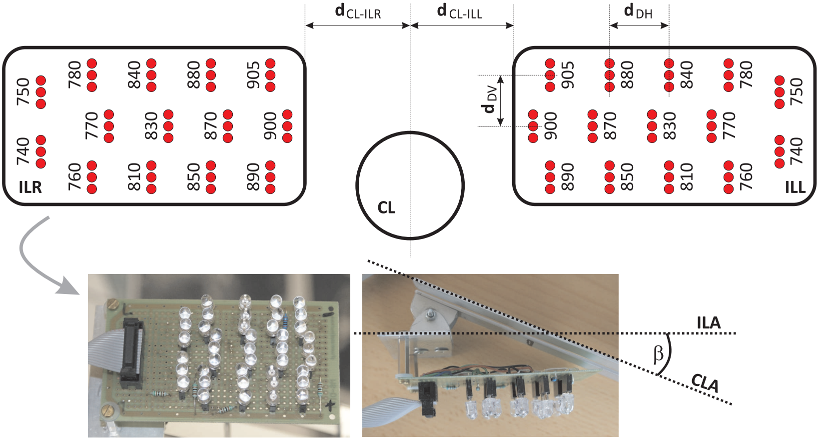
1. Possible usage: authenticity (liveness) detection or quality assessment
2. Difficult to offer low FRR (FADR) if zero FAR (FNDR) is demanded
3. May offer low FAR (FNDR) if zero FRR (FADR) is demanded (detection of approx. 95% of artefacts used in successful spoofing attacks)
4. Sensitive to segmentation errors (artefact appearance difficult to be predicted)

Agenda

Equipment

1. Analogue camera with increased IR sensitivity
2. Fixed lens with IR filter
   (100% transparency for wavelengths higher than 720 nm)
3. Two illuminants
   - placed equidistantly on the left and right sides of the lens
   - containing 14 sections of IR LEDs (each section consists of 3 LEDs and corresponds to one wavelength)
   - the spectral bandwidth of the illuminating diodes at 50% ("half width"):
     - 30nm for lambda 740-780 nm,
     - 35 nm for lambda 810-840 nm,
     - 40 nm for lambda 850-870 nm, and
     - 75-80 nm for lambda 890-905 nm.
   - LEDs power compliant with IEC 60825-1 (Ed. 1.2)

Equipment

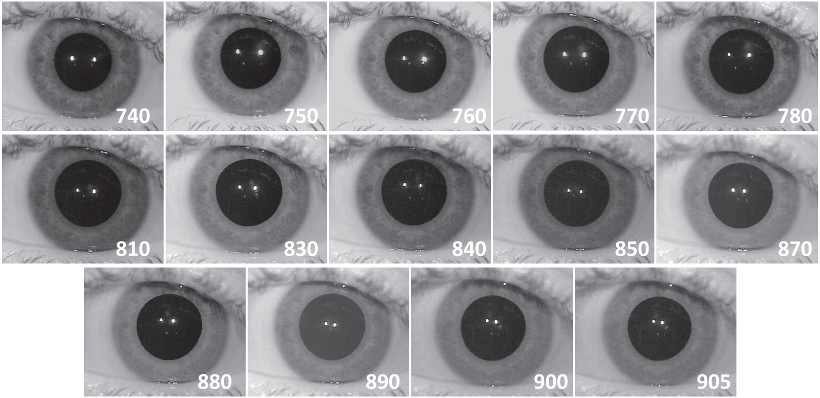


ILR, ILL: illuminants (right, left)
CL: camera lens
CLA: line perpendicular to the lens axis
ILA: line perpendicular to the illuminant axis

$d_{\text{CL-ILR}} = d_{\text{CL-ILL}} \approx$ 60mm (adjustable)
$d_{\text{DV}} \approx$ 15mm
$d_{\text{DH}} \approx$ 10-15mm
β: adjustable for best iris illumination

Database

Images for 50 different eyes (8 images per eye; a subset of a larger set for 200 different eyes was used)



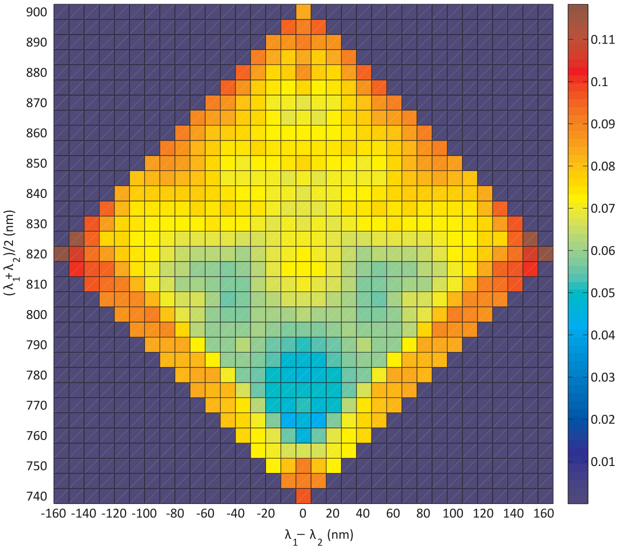
Selected results

Median EER (%) for matcher No. 1 (academic)

λ_2 (nm) verification sample \ λ_1 (nm) enrollment template	740	750	760	770	780	810	830	840	850	870	880	890	900	905
905	11.3	11.4	8.9	9.4	8.4	9.4	9.0	8.8	8.9	9.2	8.8	9.4	8.9	10.1
900	11.9	11.7	9.7	9.6	8.5	9.2	9.1	9.2	9.6	9.4	8.6	9.6	8.3	8.9
890	10.3	9.2	7.7	8.0	7.6	8.8	7.8	8.4	8.2	7.6	7.9	9.2	9.6	9.4
880	9.8	9.8	7.8	7.5	7.4	7.9	7.4	7.6	7.5	7.5	8.8	7.9	8.6	8.8
870	8.8	9.0	7.6	7.1	7.2	7.8	7.1	7.6	7.4	7.3	7.5	7.6	9.4	9.2
850	8.8	9.3	7.4	6.0	6.0	7.3	7.1	7.1	7.6	7.4	7.5	8.2	9.6	8.9
840	8.5	8.9	7.0	6.8	6.1	6.8	6.9	7.0	7.1	7.6	7.6	8.4	9.2	8.8
830	8.2	8.4	6.1	6.0	5.6	7.3	6.9	6.9	7.1	7.1	7.4	7.8	9.1	9.0
810	8.3	8.4	6.0	6.2	6.0	7.3	7.3	6.8	7.3	7.8	7.9	8.8	9.2	9.4
780	7.7	7.3	4.9	5.1	4.8	6.0	5.6	6.1	6.0	7.2	7.4	7.6	8.5	8.4
770	7.4	7.1	4.3	5.5	5.1	6.2	6.0	6.8	6.0	7.1	7.5	8.0	9.6	9.4
760	7.2	6.7	4.7	4.3	4.9	6.0	6.1	7.0	7.4	7.6	7.8	7.7	9.7	8.9
750	8.8	9.3	6.7	7.1	7.3	8.4	8.4	8.9	9.3	9.0	9.8	9.2	11.7	11.4
740	9.9	8.8	7.2	7.4	7.7	8.3	8.2	8.5	8.8	8.8	9.8	10.3	11.9	11.3

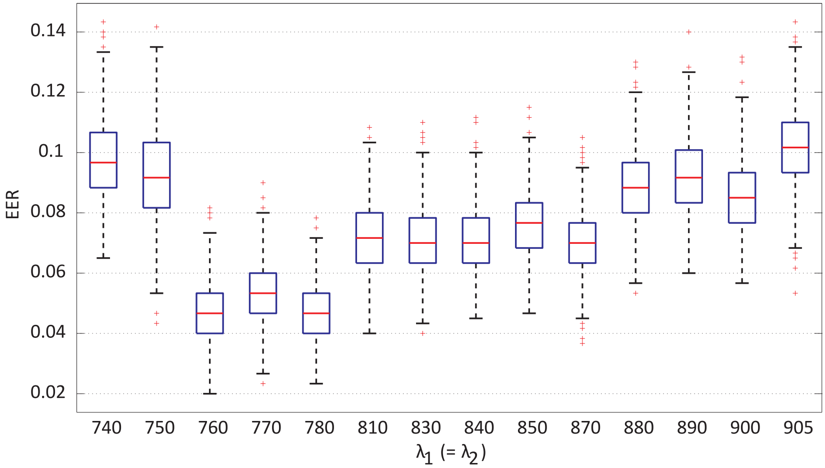
Selected results

Median EER (%) interpolated every 10nm for matcher No. 1 (academic)



Selected results

EER boxplot for matcher No. 1 (academic) when $\lambda_1 = \lambda_2$



Legend: the bottom and top of the boxes: 25th and 75th percentile; red band near the middle: median value; whiskers: 1.5 IQR; plus signs: outliers

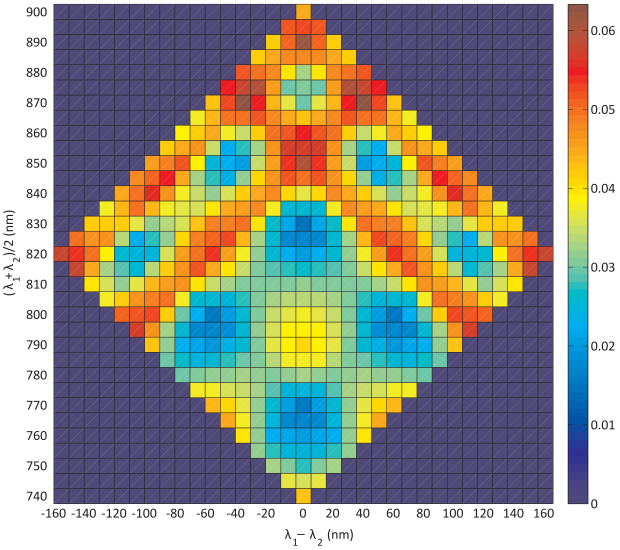
Selected results

Median EER (%) for matcher No. 2 (commercial)

λ_2 (nm) verification sample \ λ_1 (nm) enrollment template	740	750	760	770	780	810	830	840	850	870	880	890	900	905
905	5.2	4.6	3.8	3.6	4.3	4.6	3.8	4.4	5.7	4.1	4.0	5.5	5.2	4.8
900	5.8	5.0	4.1	3.8	4.5	4.3	3.8	4.4	5.6	4.2	4.2	5.4	4.6	5.2
890	5.9	5.0	4.6	4.2	5.0	5.2	4.5	5.1	6.2	4.9	4.9	6.1	5.4	5.5
880	4.1	3.2	2.7	2.4	3.2	3.4	2.3	3.5	5.1	3.0	3.4	4.9	4.2	4.0
870	3.8	3.1	2.6	2.4	3.2	3.2	2.2	3.4	5.1	3.0	3.0	4.9	4.2	4.1
850	5.6	5.3	5.0	4.7	5.2	5.0	5.0	5.2	6.0	5.1	5.1	6.2	5.6	5.7
840	4.3	3.4	3.0	2.8	3.6	3.5	2.8	3.8	5.2	3.4	3.5	5.1	4.4	4.4
830	3.0	2.4	1.9	1.6	2.5	2.7	1.5	2.8	5.0	2.2	2.3	4.5	3.8	3.8
810	3.9	3.3	2.9	2.7	3.3	3.2	2.7	3.5	5.0	3.2	3.4	5.2	4.3	4.6
780	3.9	3.1	2.8	2.5	3.4	3.3	2.5	3.6	5.2	3.2	3.2	5.0	4.5	4.3
770	3.2	2.3	1.8	1.7	2.5	2.7	1.6	2.8	4.7	2.4	2.4	4.2	3.8	3.6
760	3.4	2.5	2.3	1.8	2.8	2.9	1.9	3.0	5.0	2.6	2.7	4.6	4.1	3.8
750	3.8	2.9	2.5	2.3	3.1	3.3	2.4	3.4	5.3	3.1	3.2	5.0	5.0	4.6
740	4.4	3.8	3.4	3.2	3.9	3.9	3.0	4.3	5.6	3.8	4.1	5.9	5.8	5.2

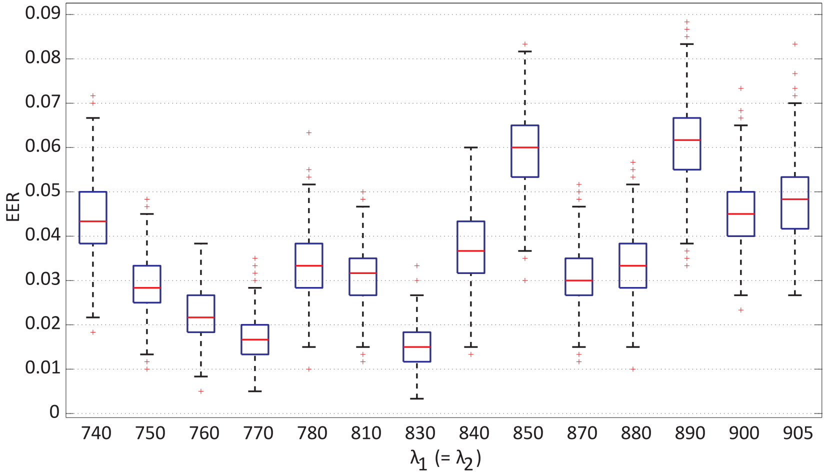
Selected results

Median EER (%) interpolated every 10nm for matcher No. 2 (commercial)



Selected results

EER boxplot for matcher No. 2 (commercial) when $\lambda_1 = \lambda_2$



Legend: the bottom and top of the boxes: 25th and 75th percentile; red band near the middle: median value; whiskers: 1.5 IQR; plus signs: outliers

Conclusions

1. Recognition performance for different wavelengths seems to be uneven
2. The interoperability among capture systems using different illumination wavelengths might not be guaranteed
3. Need for evaluations on larger datasets (ongoing) and for greater number of matchers (any parties willing to cooperate are welcome)

Contact

Adam Czajka
adam.czajka@nask.pl

Biometric Labratories
Research and Academic Computer Network (NASK)
Warsaw, Poland

Biometrics and Machine Learning Group
Warsaw University of Technology
Warsaw, Poland